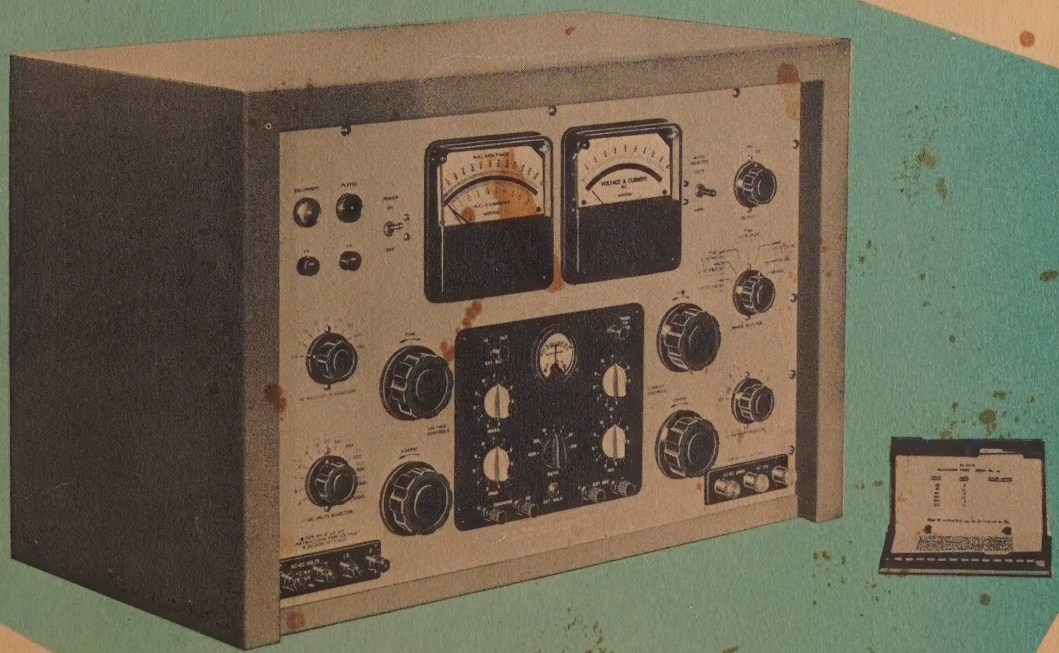
Model 829

AC-DC

INSTRUMENT CALIBRATION STANDARD

RFL

Handbook of Instructions



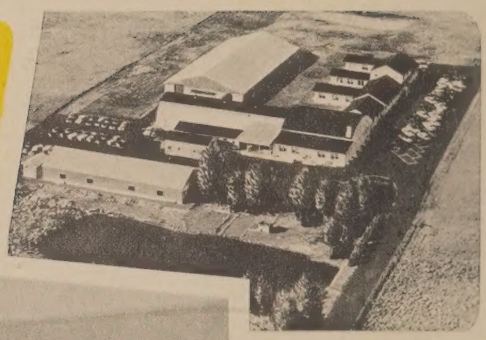
Radio Frequency Laboratories, Inc. BOONTON, N.J., U.S.A.

DESIGNERS AND MANUFACTURERS OF ELECTRICAL EQUIPMENT AND APPARATUS SINCE 1922

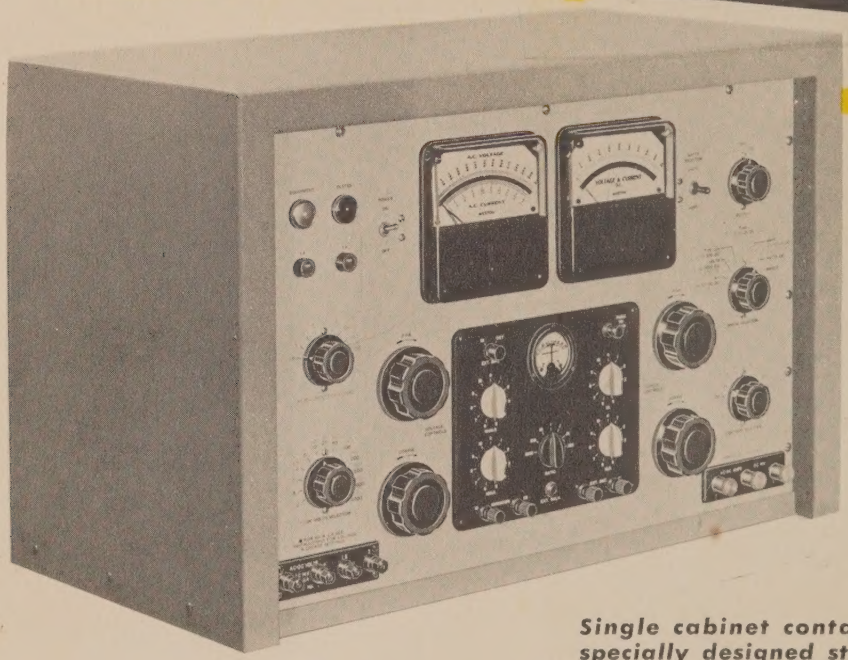
REVISED FEBRUARY 1958

ITEM 2585

WHY THE *Model 829* WAS DESIGNED



***MODERN** plant, adjacent to private airfield, has every facility for design and manufacture of precision electronic equipment.*



Single cabinet contains power supply, specially designed standard meters and complete circuits for rapidly computing instrument calibrations.

Your Model 829 AC-DC Instrument Calibration Standard is the newest addition to the most complete line of self-contained instrument standards equipment manufactured in the United States. It uses the finest components available and is designed to save you time and lost motion everytime you need to check or calibrate an electrical instrument which, in today's engineering, production and control methods, is a frequently recurring necessity.

You don't have to be a technician, nor even know how or why an electrical instrument works. The step-by-step operational procedure of the Model 829 has been refined to a minimum. A system of interlocks prevents damage to the meter you're testing, as well as the Model 829's standards, if you do make a mistake.

The instruction book describes the equipment in detail, and we hope you take time to read it. But it's not necessary for constant reference; the mechanical Autodex reference index is for your daily use or as a refresher if you forget. Every calibration step is summarized for each type and range of instrument.

The Model 829 was designed to make your calibration work easier, faster and more convenient. It offers laboratory accuracy but is built for every day use, anywhere in your plant.

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WARNING

Operation of this equipment involves the use of high voltages which are dangerous to life. Operating personnel must at all times observe all safety regulations. Do not change tubes or make adjustments inside the equipment with voltage supply on. Under certain conditions dangerous potentials may exist in circuits with power controls in the off position due to charges retained by capacitors, etc. To avoid casualties always discharge and ground circuits prior to touching them.

Model 829

AC–DC INSTRUMENT CALIBRATION STANDARD

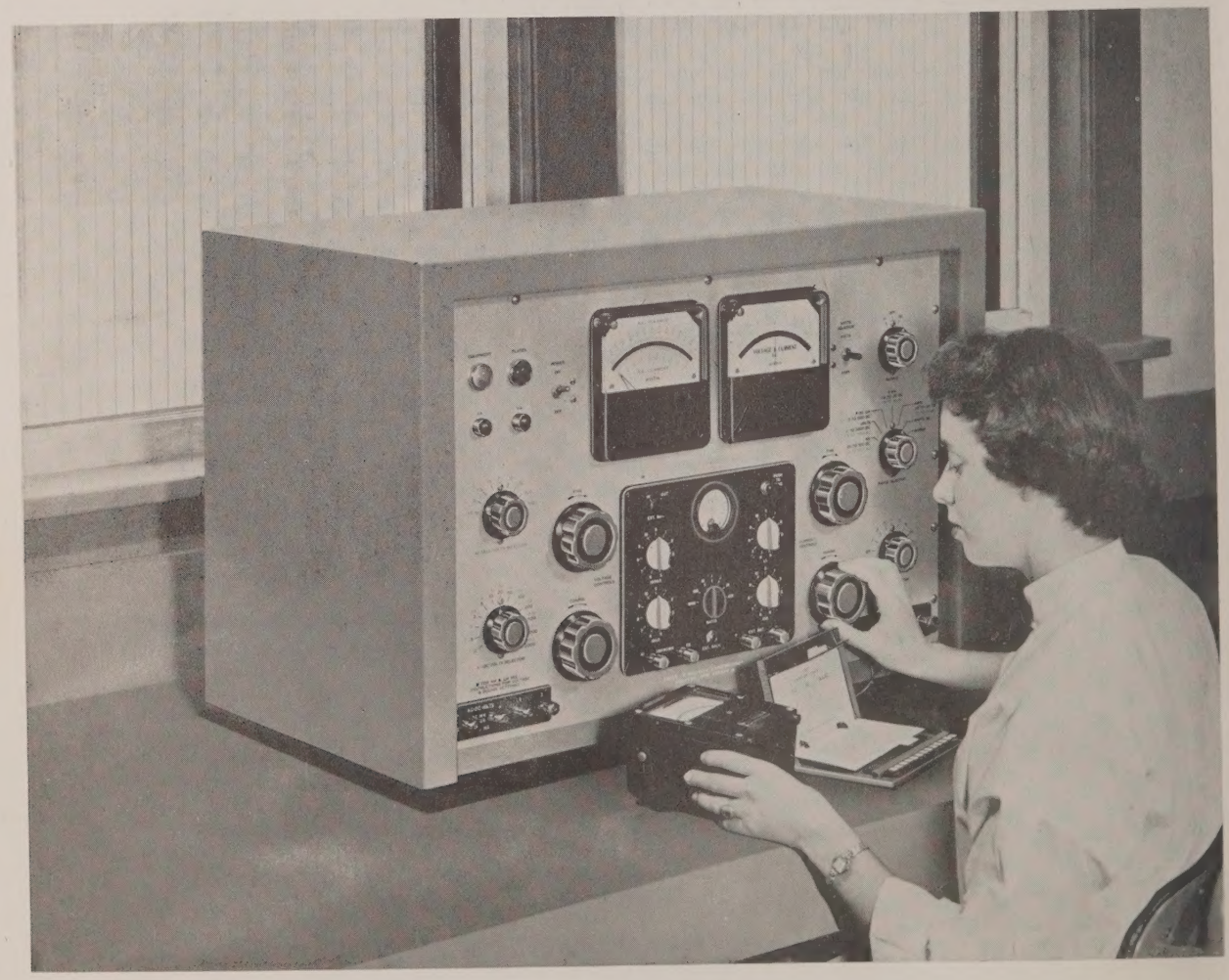


Figure 1. Front View of Model 829
AC-DC Instrument Calibration Standard

GENERAL DESCRIPTION

General

The Model 829 AC-DC Instrument Calibration Standard consists of wide range ac and dc voltage and current sources, control elements, and two standard instruments for accurately measuring the magnitude of ac or dc current and voltage that is being applied to an instrument under calibration. A Wheatstone bridge is included for instrument repair work. The equipment is entirely enclosed in an aluminum alloy cabinet as shown in figure 1.

To protect the standard instruments and controls, the front panel is recessed into the cabinet. Adequate ventilation is provided at the rear. A light-weight design permits the equipment to be easily transported and moved to the required areas in laboratories and factories.

The electrical connections to the instrument under calibration are made at the terminal posts at the lower right and left sides of the front panel. The FINE and COARSE Variacs on the right of the panel control the current output, and the FINE and COARSE Variacs on the left side of the panel control the voltage output. A two-color marking of the front panel controls differentiates the ac ranges from the dc ranges.

The equipment will calibrate dc voltage instruments between 0.25×10^{-3} and 2,000 volts full-scale, dc current instruments between 2×10^{-6} and 20 amperes, ac voltage instruments between 1.5×10^{-3} and 1,500 volts, and ac current instruments between 1.5×10^{-3} and 20 ac amperes. Since the dc voltage and dc current sections are separate and complete, this equipment may also be used to calibrate electrodynamic wattmeters by the dc method. The equipment is designed to supply the burdens of standard commercial instruments. The calibration ranges are given in the Supplementary Data section.

Calibration Charts

Before shipment the full-scale output on each range is measured on basic standards with recent Bureau of Standards calibration certificates. These readings are made to an accuracy of ±.1% and are recorded on a push-button file mechanism. A brief operational procedure is included with the calibration chart for each type of instrument. Figure 2 shows this file open for use. The calibration figures recorded are the actual voltage or current outputs when the standard instrument of the Model 829 AC-DC Instrument Calibration Standard reads exactly on the full-scale mark. A scale distribution correction chart is used to obtain the greatest possible accuracy at major down-scale marks.

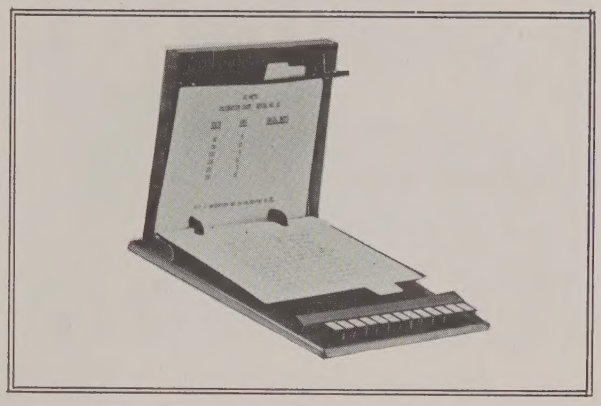


Figure 2. Calibrated Chart File, Open for Use.

Protective and Safety Features

Instruments under test are protected against accidental over-load by means of interlocks which disconnect the internal supply when range settings are changed without first returning the magnitude variable auto-transformer to zero. After interlocks have been tripped, it is necessary to return the magnitude controls to zero to reconnect the power supply to the instrument.

Resistance in the current circuits prevents excessive over-loading of the standard instrument or the instrument being tested. Voltage divider circuits are designed for a maximum no-load to full-load variation of 2 to 1.

Operating Characteristics

The frequency of the output on the ac ranges is that of the power source. The frequency of the power source may be in the range of 50 to 400 cps. The nominal line voltage should be 115 volts ±10% with a short time stability better than the accuracy to which measurements are to be made. This stability is normally obtained on lightly loaded 115 volt, 60 cps lines. In factory areas it may be necessary to supply the equipment from a 250 va Sorenson type regulator.

For frequencies other than 60 cycles, a variable frequency power amplifier of 300 va output at 115 volts may be used. The power amplifier should have less than 3% harmonic distortion.

Standard Instruments

The standard instruments are designed by the Weston Electrical Instrument Corporation for use in the

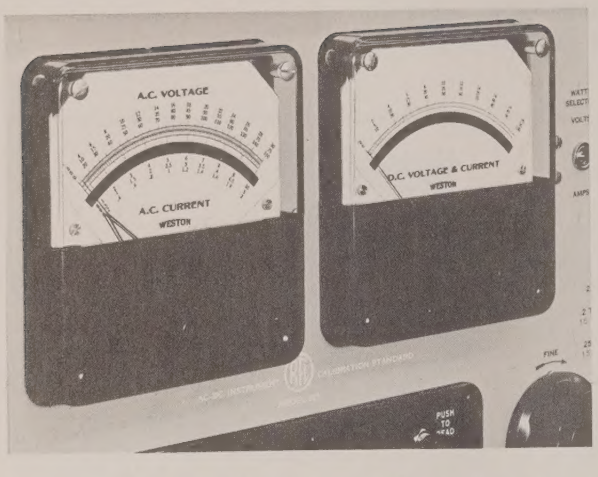


Figure 3. Standard Instruments — Weston Meters.

Model 829 AC-DC Instrument Calibration Standard. The dc standard is a basic 1 milliampere movement built into a Weston Model 921 frame. A hand-marked 5-inch mirror scale and knife edge pointer permit accurate readings. The scale is marked with a 100-division scale with figures for 20, 50, and 100 full-scale units.

The ac standard is a 100 milliampere movement adjusted for 75 volts full-scale with a series resistor built into a Weston Model 924 frame. A third binding post is provided to permit direct connection across the coils for use with the current transformer. Hand-marked mirror scales and knife edge pointers permit accurate readings. A double scale of 100 and 150 divisions is marked 2, 5, 10 for ac current and 30, 75, 150 for ac volts. Multiplication factors of ten are used for the ranges not marked.

The above standard instruments with precision dc shunts, multipliers, ac potential transformers, and current transformers permit the long-time use of the equipment to calibrate instruments to ±0.5% with the use of the calibration chart and to a guaranteed 1% over-all accuracy on all ranges at full-scale without the charts.

INSTALLATION AND ADJUSTMENT

Unpacking The Equipment

Carefully remove the external wood protecting cover, then cut the moisture barrier exposing the equipment. Inspect the unit for damage in shipment. Tighten any loose screws and nuts. The top cover of the equipment can be taken off by removing three Phillips head screws on each side, and five Phillips head screws around the front panel, and one at the lower center of the back. Inspect the internal parts for shipping damage.

Installation

Location

The Model 829 AC-DC Instrument Calibration Standard should be located in a clean room with adequate clearance behind the unit for ventilation. The equipment is to be placed on a work bench or a table.

Connection to Power Source and Ground

If the equipment is to be operated from a non-variable power source, such as the conventional power line (50 to 400 cps), the connections are made through J-101 at the rear of the equipment as shown in figure 4.

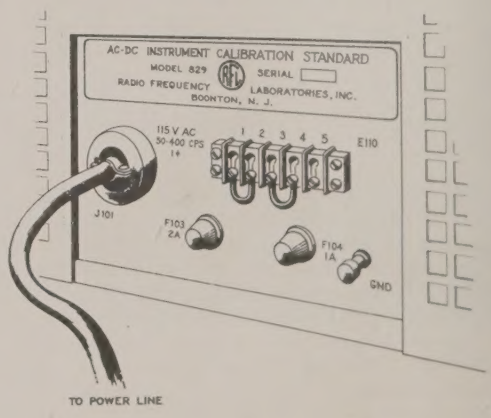


Figure 4. View of Power Connections at Rear (For Line Operation).

If the equipment is to be operated from a variable frequency, variable output power oscillator, the connections are made as shown in figure 5. This type of connection circumvents the internal Variacs and the voltage control is accomplished at the power oscillator. The case must be bonded to a good external ground or the power line conduit. The fuses F-103 and F-104 are mounted on the rear panel and protect internal measuring circuits. The 3 ampere fuses F-101 and F-102 are mounted on the front panel and are the EQUIPMENT fuses on the ac line.

Before operation set the mechanical zeros of the standard instruments by means of the small screw on the instrument case. Tap the instrument lightly while making this adjustment.

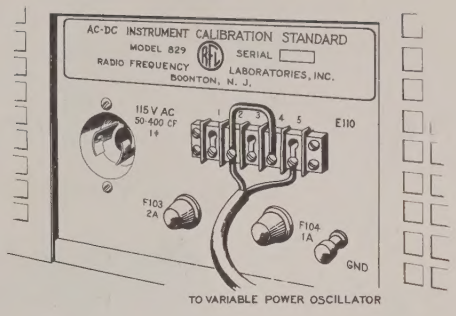


Figure 5. View of Power Connections at Rear (For Variable Frequency Input).

OPERATION

Precautions

Although many safeguards against destroying the instrument being calibrated have been constructed into this equipment, it is possible that trouble may be encountered due to faulty operation. The following precautions must be taken.

a. Do not bypass interlocks except as required for periods of repair.

b. Keep in mind that the standard instruments, precision shunts, and multipliers in the equipment are delicate in nature and are designed to give a high degree of accuracy for long periods if treated with care.

c. Turn all magnitude (VOLTAGE or CURRENT) Variac controls entirely counter-clockwise before turning off the source. All SELECTOR switches and the OUTPUT switch have been provided with protective interlocks. Before proceeding with the calibration of other ranges, the VOLTAGE and CURRENT COARSE CONTROLS must be turned to full counter-clockwise position.

d. Do not remove the instrument being calibrated while energized. Always return all instruments to zero before continuing.

e. Check all connections and control switch positions before energizing a circuit.

f. In operation the equipment is held to value and the instrument being calibrated is read. Figure 6 shows a front view of the control panel.

g. The range indicated by the SELECTOR is represented by a full-scale deflection of the standard. To determine the value of the output voltage or current, utilize the scale figures whose full-scale value when divided or multiplied by multiples of 10 result in the value indicated by the SELECTOR. The value indicated on the standard when multiplied or divided by the same multiple of 10 is equal to the output voltage or current.

Determination of DC Meter Resistance

If the dc resistance of the instrument is unknown but is required for its calibration, connect the instrument to AC-DC MA terminals. Turn POWER switch to ON. Set RANGE SELECTOR to MA position. Set bridge decade for 0 ohms. Set OUTPUT switch for DC. Beginning at the lowest AC-DC VOLTS SELECTOR value, operate VOLTAGE CONTROLS and apply enough voltage to bring the instrument under test to full-scale. Increase the decade resistance (white knobs), while holding the voltage constant, until half-scale is indicated on the test instrument. The resistance indicated on the decade dials is equal to the resistance or impedance of the instrument under test.

DC Voltmeter Calibration

The following procedure should be adhered to in setting up dc voltmeter calibration:

a. Check to see that the CURRENT and VOLTAGE CONTROLS are at zero (maximum counter-clockwise position) and turn POWER switch to ON. The EQUIPMENT pilot lamp turns on immediately; the PLATES pilot lamp has a 30 second delay.

b. Set RANGE SELECTOR to VOLTS (.2 to 2000 DC).

c. Set AC-DC VOLTS SELECTOR to desired range.

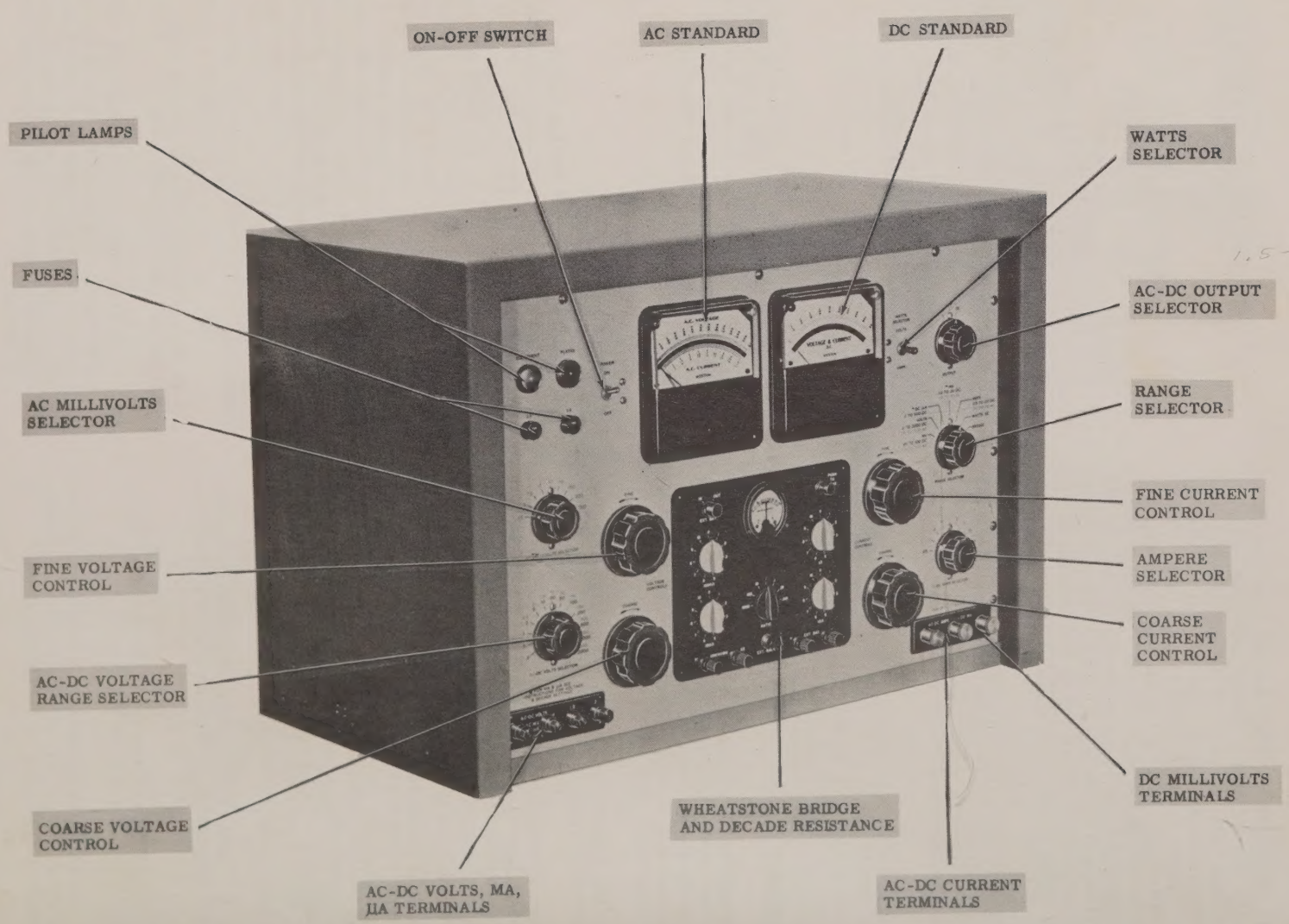


Figure 6. Front View of Control Panel.

d. Connect instrument under calibration to AC-DC VOLTS terminals.

e. Set OUTPUT switch to DC.

f. Operate the VOLTAGE CONTROLS. Read DC standard.

7 DC Microammeter Calibration

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to DC μA (2 to 500 DC).

c. Set AC-DC VOLTS SELECTOR to voltage indicated in Table 1.

d. Connect instrument under calibration to DC μA terminals.

e. Set decade resistance (white knobs) so that the total resistance of the instrument under calibration plus decade equals 10,000 ohms. (The total circuit resistance is 100,000 ohms for DC μA. See figure 7.)

f. Set OUTPUT switch to DC.

g. Operate VOLTAGE CONTROLS. Read DC standard.

8 DC Milliammeter Calibration

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to MA (1.0 to 20 DC).

c. Set AC-DC VOLTS SELECTOR to voltage indicated in Table 2.

d. Connect instrument under calibration to AC-DC MA terminals.

e. Set decade resistance (white knobs) so that the total resistance of the instrument under calibration plus decade equals 10,000 ohms.

f. Set OUTPUT switch to DC.

g. Operate VOLTAGE CONTROLS. Read DC standard.

9 DC Ammeter Calibration

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to AMPS (.05 to 20 DC).

c. Set AC-DC AMPS SELECTOR to desired range.

d. Connect instrument under calibration to AC-DC AMPS terminals.

e. Set OUTPUT switch to DC.

f. Operate CURRENT CONTROLS. Read DC standard.

10 DC Millivolt Range

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to MV.

c. Set AC-DC AMPS SELECTOR to current indicated in Table 3.

d. Connect instrument under calibration to DC MV terminals.

e. Set OUTPUT switch to DC.

f. Operate CURRENT CONTROLS. Read DC standard.

Table 1.
Voltages for Microampere Ranges.

CURRENT	VOLTAGE
2 μA	0.2 Volts
5	0.5
20	2.0
50	5.0
200	20.0
500	50.0

Table 2.
Voltages for Milliampere Ranges.

CURRENT	VOLTAGE
1 MA	10 Volts
2	20
5	50
10	100
20	200

Table 3.
Currents for Millivolt Ranges.

CURRENT	SHUNT VOLTAGE
0.05 Amp	0.25 MV
0.1	0.5
0.2	1.0
0.5	2.5
1.0	5.0
2.0	10.0
5.0	25.0
10.0	50.0
20.0	100.0

11 Electrodynamic Wattmeter Calibration by DC Methods

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to WATTS DC.

c. Set OUTPUT switch to DC.

d. Set AC-DC AMPS SELECTOR and AC-DC VOLTS SELECTOR to desired voltage and current ranges.

e. Connect wattmeter potential and current coils to AC-DC VOLTS and AC-DC AMPS terminals respectively, observing polarity.

f. Alternately place WATTS SELECTOR in VOLTS and AMPS position and operate VOLTAGE and CURRENT CONTROLS until desired range value is indicated on the DC standard in each case.

g. The product of VOLTS x AMPS = WATTS.

h. For greater accuracy reverse potential and current leads and repeat procedure. Take the average of the two readings.

12 AC Voltmeter Calibration

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to VOLTS (1.5 to 1500 AC).

c. Set AC-DC VOLTS SELECTOR to desired range.

d. Connect instrument under calibration to AC-DC VOLTS terminals. For 1.5 and 3.0 volt instruments with large current requirements use the G terminal and the 1.5 or 3.0 volt terminal.

e. Set OUTPUT switch to AC.

f. Operate VOLTAGE CONTROLS. Read AC standard.

13 AC Millivolt Calibration (Vacuum Tube Voltmeters)

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to MV (1.5 to 750 AC).

c. Set AC MILLIVOLTS SELECTOR to desired range.

d. Connect instrument under calibration to AC MV terminals.

e. Set OUTPUT switch to AC.

f. Operate VOLTAGE CONTROLS. Read AC standard.

14 Non-Inductive AC Milliammeter Calibration

(See Page 13 for Inductive AC Milliammeters.)

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to MA (1.5 to 30 AC).

c. Set AC-DC VOLTS SELECTOR as indicated below.

d. Set decade resistance (white knobs) so that impedance of instrument under calibration plus decade equals 10,000 ohms.

e. Connect instrument under calibration to AC-DC MA terminals.

f. Set OUTPUT switch to AC.

g. Operate VOLTAGE CONTROLS. Read AC standard.

Table 4.

Voltages for AC Milliampere Ranges.

CURRENT	AC VOLTAGE
1.5 MA	15
3.0	30
7.5	75
15.0	150
30.0	300

15 AC Ammeter Calibration

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to AMPS (.05 to 20 AC).

c. Set AC-DC AMPS SELECTOR to desired range.

d. Connect instrument under calibration to AC-DC AMPS terminals.

e. Set OUTPUT switch to AC.

f. Operate CURRENT CONTROLS. Read AC standard.

Operation of the Wheatstone Bridge

a. Turn POWER switch to ON.

b. Set RANGE SELECTOR to BRIDGE position.

c. Turn EXT. BAT. switch to OUT position.

d. Set RATIO switch for desired multiplier.

e. Set decade (white knobs) to approximate resistance of the unknown.

f. Set OUTPUT SELECTOR to DC.

g. Depress PUSH TO READ switch and vary decade until 0 is indicated on the null indicator.

h. Decade setting x multiplier = unknown resistance.

i. For greater sensitivity for resistance values of 50,000 ohms and up, turn EXT. BAT. switch to IN position and connect jumpers between AC-DC VOLTS terminals and the bridge EXT. BAT. terminals, observing polarity. Follow procedure as outlined for dc voltmeter calibrations and apply the following voltages to the bridge:

RESISTANCE	VOLTAGE
50 K to 2 Megohm	20 V DC
2 to 4	50
4 to 10	100
10 to 11	200

THEORY OF OPERATION

Circuits for Calibration of DC Voltmeters, DC Milliammeters, and DC Microammeters

The dc voltage circuit is set up by switches and includes a variable one-half wave power supply, voltage dividing networks, a standard dc instrument, and precision multiplier resistors. Figure 7 shows the general arrangement of the circuit parts.

The FINE and COARSE Variacs control the voltage on the primary of the potential transformer and, therefore, the output dc voltage. The AC-DC VOLTS SELECTOR connects the required tap on the potential transformer, selects the voltage dividing networks, and determines the instrument multiplier for the desired voltage range. The OUTPUT switch connects the voltage supply directly to the AC-DC VOLTS terminals when the RANGE SELECTOR is set to VOLTS. For dc microamperes the 10,000 ohm decade resistor and the 90,000 ohm fixed resistor are connected into the circuit. With the decade resistor, enough resistance is added to make the total circuit resistance, including the instrument under test and the 90,000 ohm fixed resistor, equal to 100,000 ohms. The microampere output for each range is calculated by dividing the voltage indicated by 100,000. For dc milliammeters only the 10,000 ohm decade resistor is used in the circuit, and the calculations are based on the 10,000 ohm value.

Circuits for Calibration of DC Ammeter and DC Millivoltmeter

The current circuit uses a variable full-wave current supply, current limiting resistors, a precision shunt, and the dc standard meter. The functional diagram of figure 8 shows the electrical arrangement of the components. The output ac ripple at full-scale is less than 2% on the 20 ampere range and reduces to less than 0.5% on the .05 ampere range.

Calibration of AC Wattmeters by DC Methods

Most electrodynamic ac wattmeters can be checked with dc voltages and currents. When the OUTPUT switch is at DC and the RANGE SELECTOR is at WATTS DC, both the voltage and current sides of the equipment are active. The WATTS SELECTOR lever switch places the dc standard instrument in either the multiplier circuit of the voltage side or the shunt circuit of the current side. As the instrument is transferred from a circuit, an equivalent resistance is connected in its place in order not to change the output current or voltage while the other is being adjusted.

Circuit for Calibration of AC Voltmeters, AC Millivoltmeters, and AC Milliammeters

The ac voltage circuits are set up by switches as shown in figure 9. The switches are shown set up for 300 volts ac. The potential transformer is an accurately wound and tapped unit with the turns ratios set so that under unloaded conditions the output voltages are about .2% high and with full burden applied are about .2% low. The ac millivolt ranges are for the calibration of vacuum tube voltmeters.

For ac milliammeter calibration, decade resistor (R102) is connected in series with the ac milliammeter under test. Enough decade resistance is then added (by adjusting the white knobs) to the ac resistance of the instrument under test so as to make the circuit have a total impedance of 10,000 ohms at the frequency of calibration.

When using 10,000 ohms as reference total circuit impedance, the various milliampere ranges covered by the Model 829 will require the voltage sources given in Table 4.

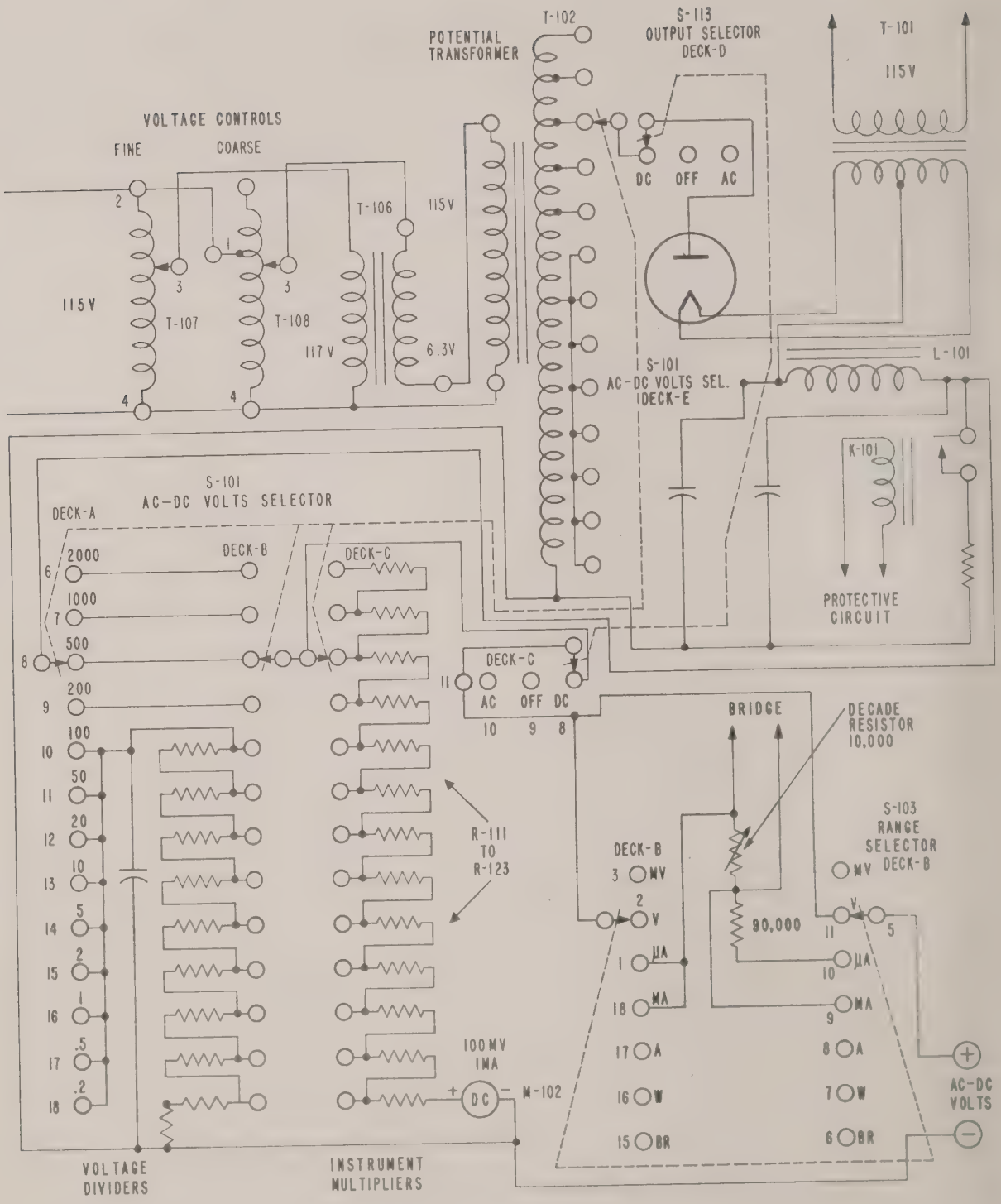


Figure 7. Functional Diagram for DC Voltmeter, DC Milliammeter, and DC Microammeter Calibration.

To set the decade resistor properly so as to give an impedance of 10,000 ohms when in series with the ac milliammeter under test, instrument reactance (X_m) and ac resistance (R_{mac}) values at the desired frequency must be known. An inductance bridge will readily give both X_m and R_{mac} values. The instrument will be inductive throughout the frequency range specified by its manufacturer, and its ac resistance will be approximately equal to the dc resistance of its winding, provided the instrument is used within the frequency range specified by the manufacturer. Both frequency and dc resistance are usually stamped on the face of the instrument. However, check dc resistance to make sure indicated value is correct.

If X_m measures less than 400 ohms, decade resistor setting equals the difference between the ac or dc resistance and 10,000 ohms. If X_m measures 400 ohms or greater, refer to the table of X_m and R_t values at the end of this manual. Find instrument X_m value and note corresponding R_t value. Then subtract the instrument ac or dc resistance value from R_t. The difference equals decade resistor setting.

In the event an inductance bridge is not available, another convenient method for arriving at X_m is by means of the instrument impedance Z_m. A variable resistor is connected in series with the instrument and voltage, the voltage having a frequency equal to

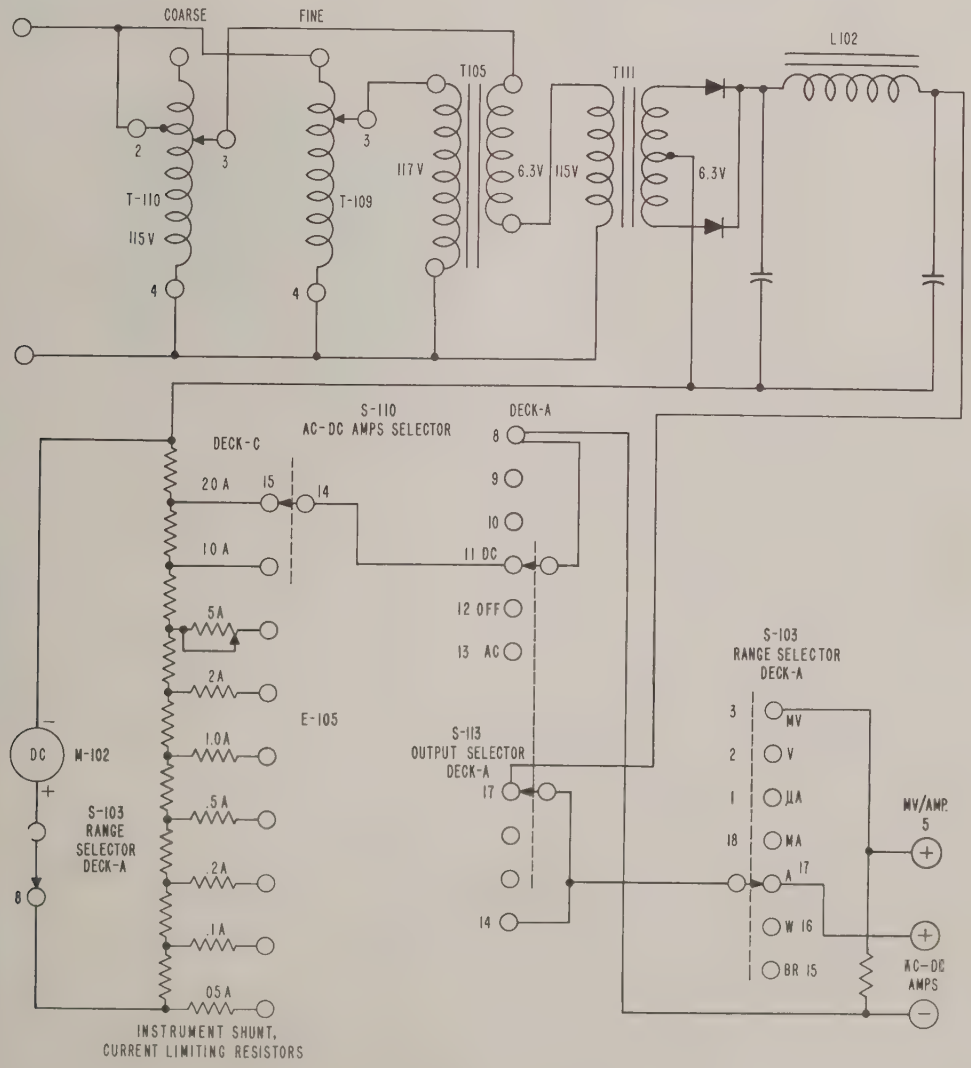


Figure 8. Functional Diagram for DC Ammeter and DC Millivoltmeter Calibration.

the calibration frequency. Vary resistance until the voltage drop across it is exactly equal to the voltage drop across the instrument. The series resistance needed for equal voltages equals instrument impedance. Use a vacuum tube voltmeter for negligible loading.

HOW TO USE CHART FOUND AT THE END OF THIS MANUAL IN CONJUNCTION WITH THE INSTRUMENT IMPEDANCE TO DETERMINE DECADE RESISTOR SETTING:

Given an ac milliammeter whose impedance (Z_m) at 400 cps equals 689 ohms and ac resistance (R_{mac}) is 279.6 ohms, find decade resistor setting.

On the series impedance chart (attached to back cover) first locate on the abscissa (horizontal scale) the ac resistance (R_{mac}) of 279.6 ohms. At that point strike a vertical line until it intersects an impedance radius equal to 689 ohms. Then at that point of intersection strike a horizontal line to the left until the X_m ordinate value (vertical scale) is reached. The X_m value in this case equals 629.59. Next, turn to the table of X_m and R_t values and find X_m equals 629.59 or a value closest to it. Then read corresponding R_t value. Now subtract the R_{mac} value from the R_t value.

Closest value to X_m of 629.59 is 600 ohms and corresponding R_t value is 9982. Subtract from 9982 the R_{mac} value of 279.6 ohms. The difference is 9702.4 ohms, which is the decade resistor setting needed at the calibration frequency in order to make

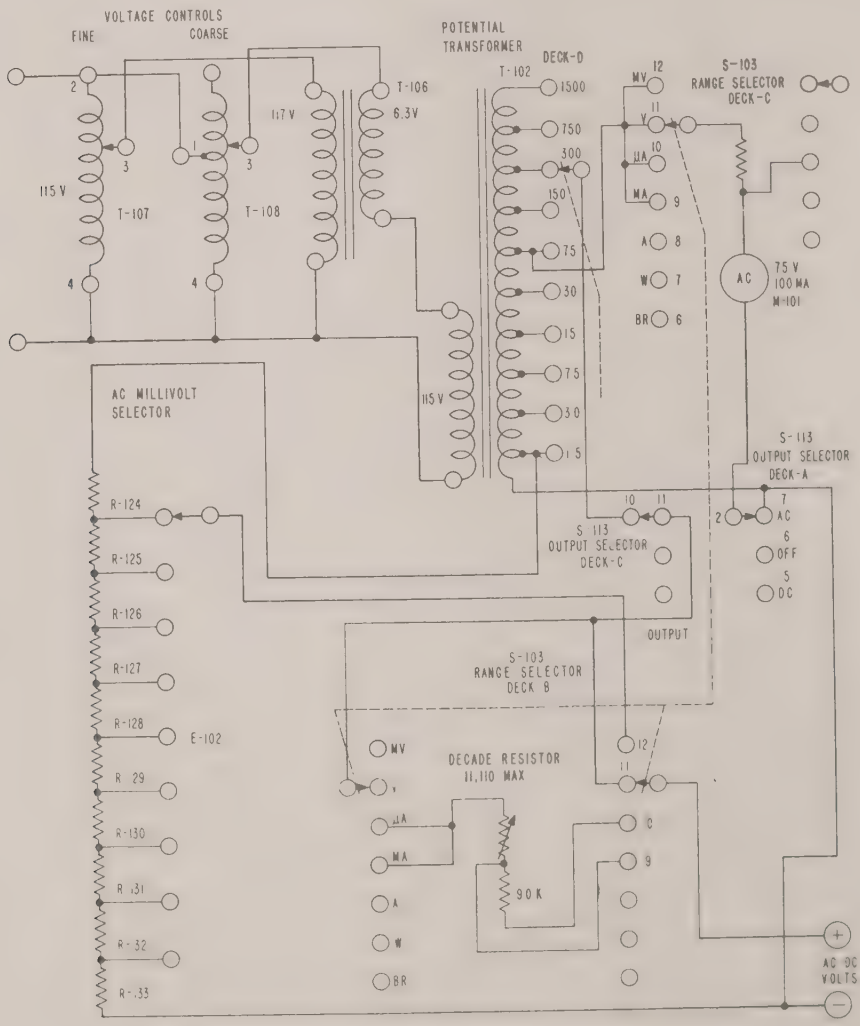


Figure 9. Functional Diagram for AC Voltmeter, AC Millivoltmeter, and AC Milliammeter Calibration.

a total circuit impedance of 10,000 ohms. Closest setting on the decade resistor is 9700 and so it is set at 9700.

Note that the series impedance chart is scaled off from 0 to 10 on both vertical and horizontal axes. Therefore, when working with instrument parameter values greater than 10 but less than 100, let the number 1 point be equal to 10. Then follow both scales with equal increments through to 100. Likewise, with parameter values greater than 100 but less than 1000, let the number 1 point be equal to 100 and work up equal increments on both scales to 1000. For parameter values greater than 1000 but less than 10,000, number 1 is set at 1000 and follow up on both scales with equal increments to 10,000.

CAUTION

Both vertical and horizontal scales must be identical, so that the impedance radii fall on equal horizontal and vertical magnitudes.

This method for computing decade resistor setting is accurate to within 0.2%.

Circuit for Calibration of AC Ammeters

Figure 10 shows the arrangement of the electrical parts for ac current calibrations. The first six

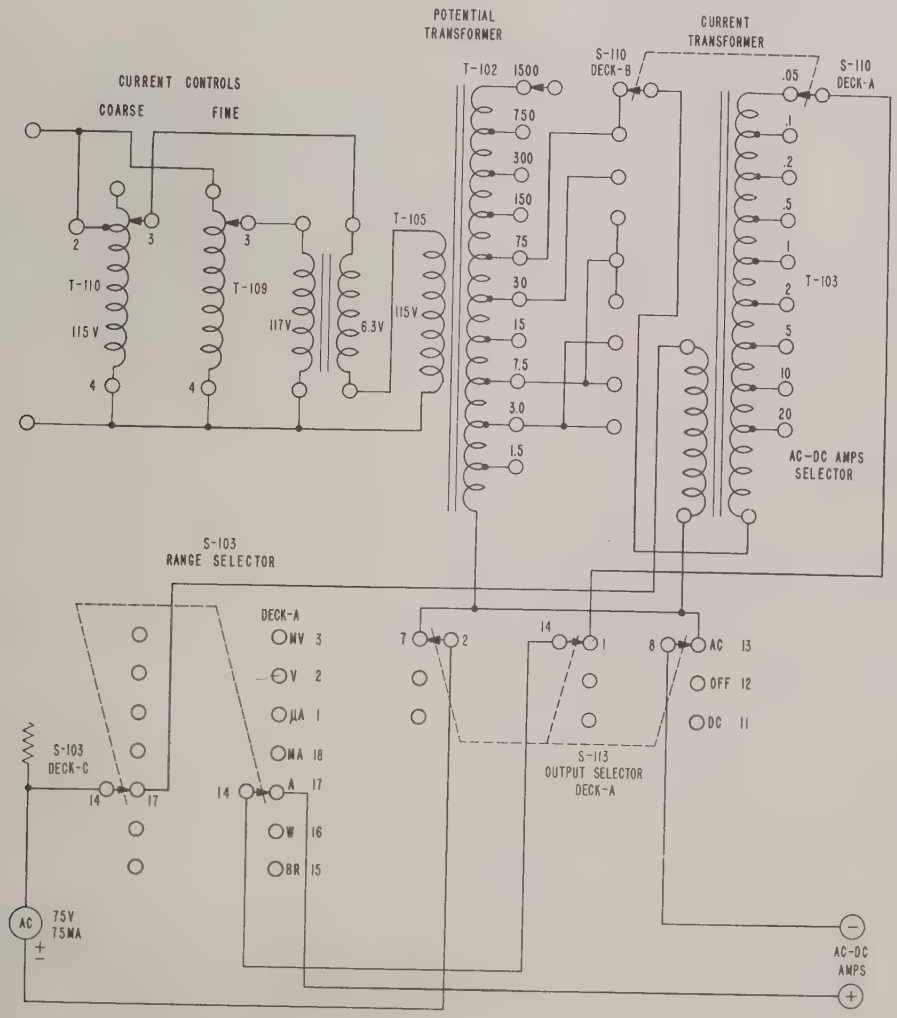


Figure 10. Functional Diagram for AC Ammeters.

windings of the potential transformer are used to supply the ac current to the current transformer and external load. The ac standard instrument is used as a basic 75 MA instrument by connecting the current transformer directly across the field coils. The SELECTOR switch determines the proper taps on the potential and current transformers for the range desired.

Figure 11 shows a simplified schematic of the control circuits. The function of the control circuit is to remove power from the equipment and discharge the high voltage capacitors whenever the equipment is turned off or a selector switch is moved, unless the VOLTAGE and CURRENT CONTROLS are at zero (the maximum counter-clockwise position). Micro-switches on each switch shaft break the holding circuit of the relay whenever the switch is moved. The circuit also discharges the capacitors in the high voltage power supply at the instant the VOLTAGE and CURRENT CONTROLS are returned to zero.

When the POWER switch is turned to ON, the green EQUIPMENT lamp lights and 30 seconds later the thermal time delay relay closes and applies power to the holding relay, which closes and applies power to the equipment when the VOLTAGE and CURRENT CONTROLS are at zero and their micro-switches are closed.

As the controls are moved up-scale the micro-switches open, but power is maintained on the equipment by the holding relay. Five micro-switches attached to the shafts of the selector switches are in the coil circuit of the holding relay. A small movement of the shaft of any of these SELECTOR switches will break the current in the holding relay coil and let it drop out to remove the power from the equipment. The COARSE Variac controls must be returned to zero to energize the holding relay again. The high voltage relay is normally closed and so requires current to hold it open. The current is supplied through the normally closed contact of the micro-switch on the COARSE voltage Variac. At zero position of the Variac this contact opens, stopping current flow through the high voltage relay which switches a 10,000 ohm bleeder resistor across the high voltage capacitors and discharges them.

Sources of Error in Instruments

Reading Errors

In general, the construction of the pointer and scale is such that readings can be estimated to one-tenth of a scale division. This is possible over most of the scale on moving coil type DC instruments and wattmeters. AC ammeters and voltmeters have crowded scales and usually only half to full-scale can be read accurately.

Most precision instruments have mirrors behind the pointers to allow the reader to move his eyes until the reflection is covered by the pointer, thus eliminating parallax.

If minor fluctuations in readings are observed, the readings should be averaged mentally. Large fluctuations prohibit accurate calibration.

Electrical Errors

SHUNTS. Care must be taken that shunts are not damaged mechanically. All connections to shunts for test must be firmly bolted with clean contacts. Do not over-tighten the bolts and distort the shunt.

EXTERNAL SHUNT AMMETERS. External shunt ammeters must be calibrated with the same set of leads connecting the shunt and the millivoltmeter as used with the instrument. When connecting the millivoltmeter to the shunt, care must be taken that all contacts are clean and tight. Examine the leads for breaks.

TEMPERATURE. Electrical instruments are affected by temperature. The temperature is determined by internal heating and the ambient.

The temperature effect is to weaken the springs and cause the instrument to read high by $0.03\%/C^{o}$. In iron instruments the permeability of the iron decreases about the same amount, compensating for the spring constant change. The magnetic field of most instrument magnets weakens with increase of temperature. The temperature coefficient for copper wire is $+0.4\%/C^{o}$ rise. In voltmeters the magnitude of this change is reduced by series resistors of zero temperature coefficient wire. Ammeters without shunts are not temperature sensitive. Ammeters with shunts are usually temperature compensated; if not, the temperature errors can approach the temperature coefficient of copper.

STRAY FIELDS. Stray fields from connecting wires may cause inaccuracies in the calibration of moving coil ammeters and voltmeters. If stray DC fields are suspected, move the connecting wires. Stray fields will cause a percentage error throughout the scale. DC panel instruments that are intended for use in steel panels must be calibrated in a steel panel. A steel panel distorts the normal field of the internal magnet and changes the readings.

ELECTROSTATIC ATTRACTION. Electrostatic forces many times exist between the instrument pointer and the glass cover. These surface charges must be dissipated by breathing upon the glass before starting the calibration procedure.

Mechanical Errors

FRICTION. Before calibrating an instrument, it should be checked for friction. This is done by energizing the instrument and slowly moving the pointer over the whole scale, stopping at several points. Excessive friction will be evident by a sudden change of reading when the instrument is tapped. Excessive friction may be due to a cracked jewel or other injury due to dropping, buckling of the paper scale, projecting hairs and fibers, dust, or magnetic particles in the air gap.

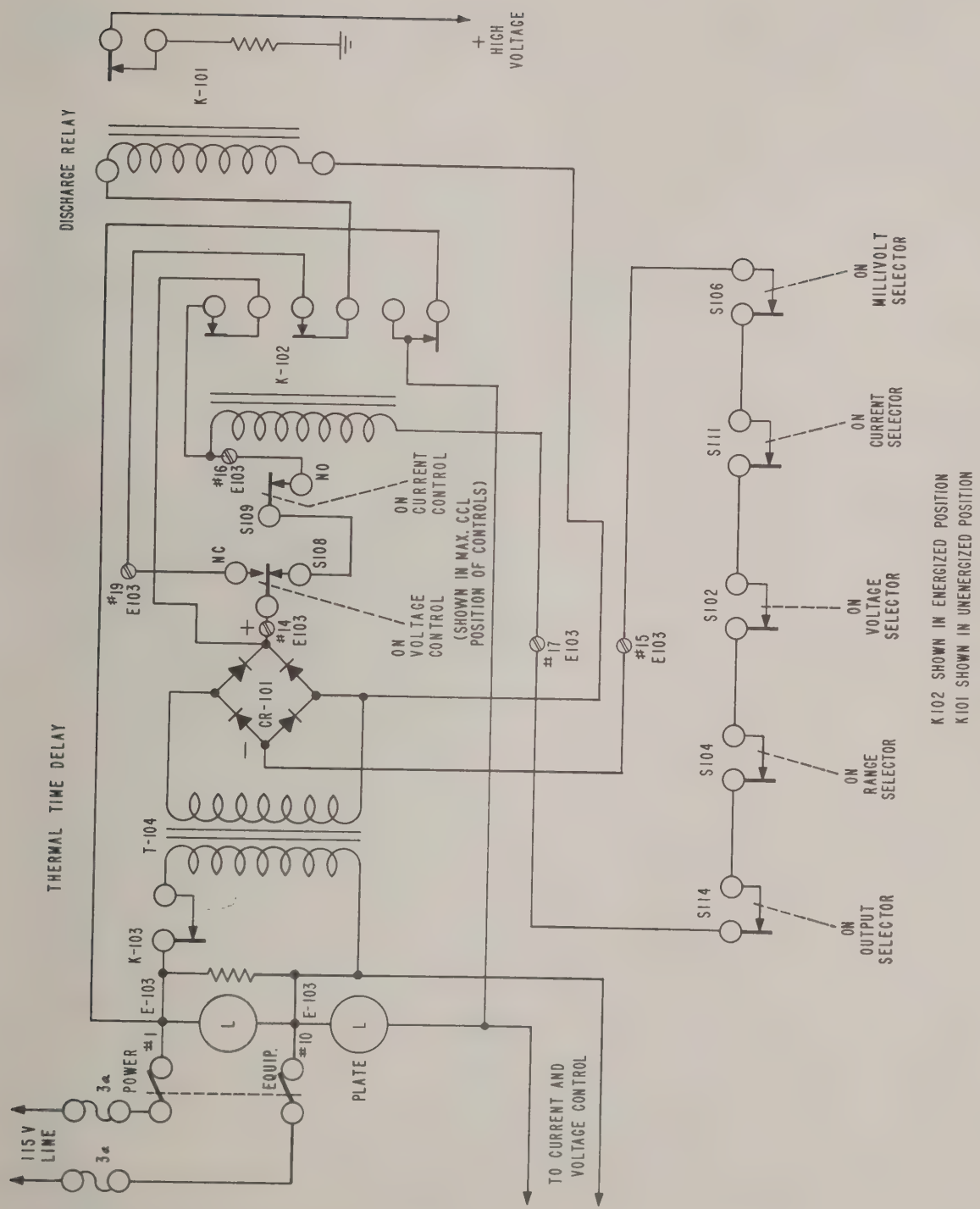


Figure 11. Simplified Schematic Diagram of Control Circuits.

SPRINGS. The zero may shift due to the mechanical yielding of the spring. A screw on the face of the instrument is usually provided to correct this.

BALANCE. The moving system of an instrument should be in good balance. Good balance is checked by bringing the instrument up to half-scale reading, then placing it successively on its near side, right side, and left side with no (or very small) change in reading. Instruments should always be calibrated in the same position as used.

Use of Model 107A Magnet Charger in Instrument Calibration

After repairing an electrical instrument, and particularly after disassembly of the magnet structure, it is usually necessary to recharge the magnet. This operation can be quickly and conveniently accomplished by using the RFL Model 107A Magnet Charger. A typical instrument assembly mounted and ready for charging on the standard bar supplied with every Model 107A is shown in figure 12.

In every case the magnet is saturated with one or two pulses and must then be treated for both stability and top mark sensitivity. This pull-down process or treating is mandatory with electrical indicating instruments and is usually done using a controlled ac field. An even better method is provided by the Model 889 Magnetreater.

Use of Magnetreater

The Model 889 Magnetreater is an accessory for use with the Model 107A Magnet Charger, and together they form a highly controllable, easy-to-operate demagnetizer. The Magnetreater will accurately adjust the flux level to any desired point and, when the Model 829 AC-DC Standard is used to supply the reference voltage or current into the instrument being treated, accuracies to a fraction of a per cent can be attained.

The Magnetreater is a desirable device for treating any type of permanent magnet, but it is particularly valuable for treating the newer core type magnets, where the older ac coil method of treatment requires unusually high currents and skilled operator techniques.

Figure 13 shows a complete set-up for magnetizing, treating and calibrating a core type electrical instrument. This type requires a special charging fixture which is also shown.

Figure 12. Front View of Model 107A Magnet Charger with an Instrument in Charging Position.

Figure 13. Demagnetizing an Instrument Magnet with the Model 889 Demagnetizer Attachment.

MAINTENANCE

General

Periodic inspection should be made to see that all screws and bolts are tight. If trouble should develop in the precision instrument transformers T-102 and T-103 or the instrument shunts E-104 and E-112, they should be replaced from the factory and no attempt made to repair them. The switches and controls are equipped with micro-switch interlocks operating from the detent mechanism. These interlocks may require periodic adjustment. Figure 14 shows cover removed and side plates loosened.

Trouble Chart

Table 5 contains a list of troubles and operational difficulties which may be encountered. In the second and third columns are listed their probable causes and recommended remedies. Refer to figure 15.

Calibration Check

In the design of the Model 829 AC-DC Instrument Calibration Standard specific emphasis was placed on long-time stability and the maintenance of calibration accuracies. If not subjected to abnormal usage this equipment will maintain its accuracy for many years. It is recommended, however, that a periodic spot check be performed every 6 months at which time a few dc current and voltage ranges as well as ac voltage and current ranges should be calibrated against standards such as the Type K Potentiometer, or a 0.25% AC-DC meter of known accuracy. This is accomplished by simply placing the standards across the Model 829 output terminals and setting the Model 829 to full-scale value on the ranges calibrated.

The panel meters in the Model 829 are checked in the factory during final calibration. A record is made of the full-scale sensitivity of each panel meter and referenced filed for each serial numbered equipment. This sensitivity is marked on each meter. A replacement or repair of a meter can be accomplished by removing it from the equipment and returning it to the factory. This eliminates returning the entire Model 829 AC-DC Instrument Calibration Standard to the factory for recalibration.

WARNING

This equipment operates at dangerous voltages. Men have been killed by very low voltage circuits. As little as 30 volts may be fatal under the proper combination of circumstances. Haste, heedlessness, attempts to work where there are distracting noises, and attempts to carry on a conversation while servicing lead to personnel and materiel casualties.

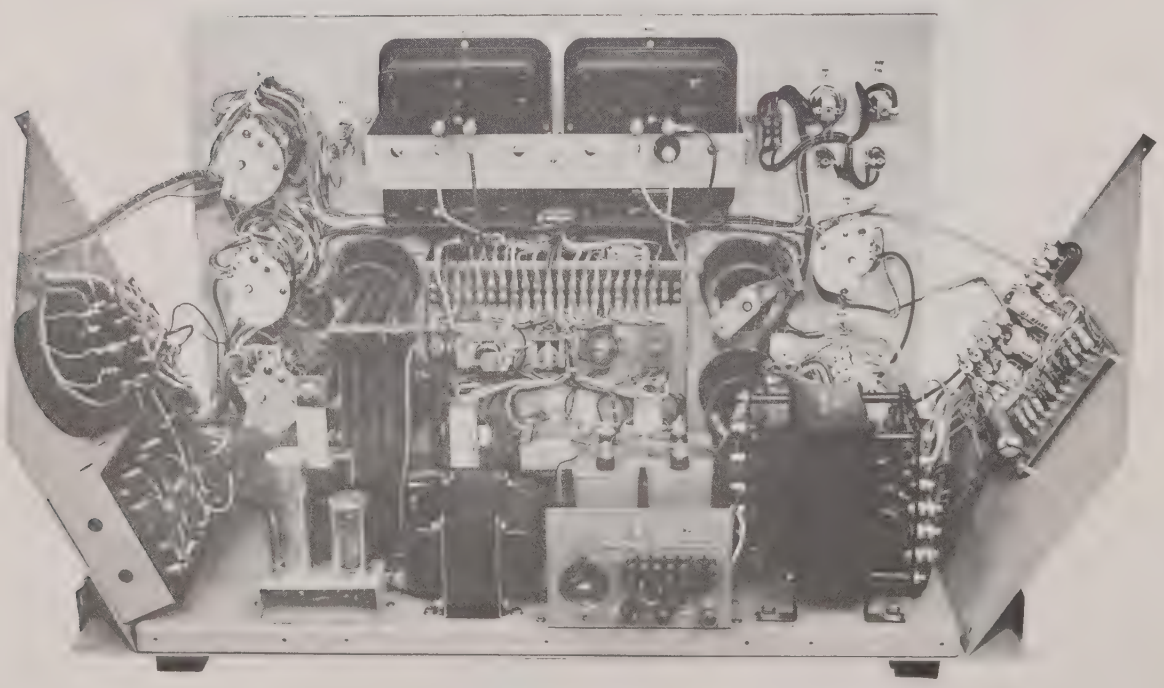


Figure 14. Top View of Model 829 AC-DC Instrument Calibration Standard with Side Panels Loosened for Servicing.

Table 5. Trouble Chart

DC SECTION

SYMPTOM	CAUSE	REMEDY
DC VOLTS		
a. No voltage output. No standard meter reading. I-102 does not light.	Jumpers on E-111.	Check for proper connection of jumpers.
	Blown fuse F-101. F-102.	Replace fuse.
	Faulty equipment switch S-112.	Check and replace if necessary.
	Faulty jack J-101.	Check and replace if necessary.
b. No voltage output. Pilot lamp I-101 does not light.	Faulty thermal delay relay K-103.	Check resistance between contacts 2 and 3 and measure heater resistance; approximately 6000 ohms.
	Open interlock circuit.	Check to see that both COARSE CONTROLS are fully counter-clockwise.
		Check to see that all switch detents are fully seated.
		Check continuity of interlock switch circuits; should show short circuit from terminal #17 to terminal #20 of E-103.
	Faulty transformer T-104.	Check T-104.
		Primary resistance 22 ohms. Secondary resistance less than 1 ohm. Secondary voltage 15 volts.
	Faulty selenium rectifier CR-101.	Check AC volts, input 15 volts.
		Check DC volts, output 12 volts.
	Faulty relay K-102.	Check for 12 volts dc across coil when thermal delay relay closes. Check relay contacts.
c. No voltage output. No standard meter reading.	Fuse F-104 open.	Check and replace if necessary.
	Relay K-101 fails to open when COARSE VOLTAGE CONTROL is rotated clockwise.	Check for 12 volts dc across relay coil when COARSE VOLTAGE CONTROL is turned clockwise. If 12 volts dc is present across coil, check continuity of relay coil, approximately 26 ohms. Check relay for sticking contacts.
	Open interlock circuit.	Check continuity of terminal board E-103. (1) Disconnect from line. Should show short circuit from #15 of terminal board E-103 to #17 of E-103; (2) with COARSE VOLTAGE and CURRENT CONTROLS at CCL position, a short exists between terminals #14 and #16; open between #14 and #19; (3) short circuit exists between #15 and #17 when all interlocks are closed.

Table 5. Trouble Chart, (cont'd).

SYMPTOM	CAUSE	REMEDY
	Faulty 836 rectifier tube.	Check and replace if necessary.
	Faulty filament transformer T-101.	Check AC volts to primary - 15 volts from #7 to #8 on E-111. Check resistance of primary of T-101. Disconnect black and black and red leads from rear of E-111. Terminals #7 and #8 should show a resistance of 42 ohms across these two leads.
	Shorted filter capacitor C-101 and C-102.	Check and replace if necessary.
	Open contact in AC-DC VOLTS SELECTOR S-101.	Check continuity.
	Short in AC-DC VOLTS SELECTOR circuit S-101.	Disconnect one side of dc standard meter. Hold relay K-101 open. From #19 of A deck, S-101 to minus volts terminal resistances should read as follows: Position of S-101 - .2 to 100 volts - 1765 ohms; 200 to 2000 volts - ∞ .
d. Voltage is present at output terminals, but standard meter does not read.	Faulty meter.	Disconnect dc meter from circuit and insert 1 MA dc meter in its place. If 1 MA meter reads as voltage controls are increased, this indicates that standard meter is defective.
	Open multiplier.	Disconnect one side of dc standard meter M-102 and check resistance of multiplier.
	Switching circuits.	Disconnect one side of dc standard meter M-102. Check S-101 for open contacts as short circuit to ground.
e. Standard meter reads, but no voltage is present at voltage output terminals.	Switching circuits.	Open contact on wiring in S-101, S-103, or S-113. A check should show continuity for #19 B deck S-102 to positive voltage output terminal.
DC MILLIAMPERES		
a. No current at MA output terminals. No standard meter reading.	Check as per DC Volts.	
b. Current at current output terminals, but standard meter does not read.	Check as per DC Volts.	
c. Standard meter reads, but there is no current at output terminals.	Switching circuits.	Check contacts in S-113 and S-103.
	Open decade resistor.	Check resistance of decades.

Table 5. Trouble Chart, (cont'd).

SYMPTOM	CAUSE	REMEDY
DC MICROAMPERES		
a. Same as milliampere symptoms.	Same as milliampere, with the addition of a possible open 90 K resistor R-147.	
DC CURRENT .05-20 AMPERES		
a. No current present at current terminals; standard meter does not read.	Check interlocks.	Check and replace if necessary.
	Blown fuse F-103.	Check for 8 volts dc on terminal board E-111 from #1 to #2.
	Faulty current supply circuit.	Check for 12 volts ac from #3 to #4 of E-111. Check continuity and for short circuit to chassis on choke L-102.
		Check C-104 and C-108 for short circuit.
		Check for 115 volts ac into T-111; #6 to #8 of E-111.
		Check resistance of primary of T-111. Disconnect leads from T-111 going to #6 and #8 of E-111. Resistance across these leads is approximately 2 ohms.
	Switch circuit.	Check S-113 and S-103.
	Faulty shunt E-104.	Check and replace. Do not attempt to repair. Return shunt to factory for repairs.
	Faulty current limiting resistors .05 to 5 amp position.	Check resistors R-135 through R-141.
DC WATTS		
a. No standard meter reading. No output.	Voltage or current sections inoperative.	Check as in DC Voltage and DC Current sections.
		Check through S-103 in watts position.
b. Output is present at terminals, but standard meter does not read in either position of WATTS SELECTOR S-107.	Faulty WATTS SELECTOR S-107.	Check contacts of S-107.
	Faulty voltage measuring circuit.	Check as per voltage troubles.
	Faulty current measuring circuit.	Check as per current troubles.

Table 5. Trouble Chart, (cont'd).

SYMPTOM	CAUSE	REMEDY
DC MILLIVOLTS		
a. No output. No meter reading.	Same as DC Current causes.	See DC Current failure remedies.
	Faulty millivolt shunt E-112 or switching circuit of S-103.	Check connections to millivolt shunt E-112. Check continuity of S-103.
BRIDGE		
a. No reading.	AC power supply circuit.	Check as per DC Current troubles.
	Check for presence of 8 volt dc across #2 and #6 of E-103.	If voltage is present it shows supply is operating. If no voltage, check continuity through S-103 and S-113 back to CR-102 and T-111.
	Meter.	Check null indicator as a microammeter using 829 standard equipment.
b. Meter shows excessive deflection with any setting of decade and/or ratio dial.	Open decade or ratio coil.	Check decade and coils for continuity.
	Defective or dirty switch contact.	Repair, clean or replace. Check S-117 and S-115.
		Check J-102. Clean contacts if necessary.
c. No external galvanometer reading. Internal galvanometer reads properly.	Faulty jack J-102.	Check J-102. Clean contacts, replace jack if necessary.

AC SECTION

AC VOLTS		
a. See a and b under DC Volts. Check accordingly.		
b. No voltage at output. No standard meter reading.	Fuse F-104.	Check and replace if necessary.
	Potential transformer T-102.	Check continuity across primary (115-115). Check resistance of primary of potential transformer, approximately 1 ohm.
	Switching circuit.	Check continuity of S-103 and S-113.
c. Standard meter reads, but no voltage across output terminals.	Switching circuit.	Check S-103 and S-113. Note 1.5 and 3.0 volts go directly to terminal and also through S-103 and S-113.

Table 5. Trouble Chart, (cont'd).

SYMPTOM	CAUSE	REMEDY
d. Voltage is at output terminals, but standard meter does not read.	Meter circuit.	Check for 75 volts at 75 volts tap of T-102 with power applied to primary. CAUTION: Extremely high voltages are present on other terminals of this transformer. Exercise extreme care. Check standard meter, M-102. Check meter switching circuits S-103 and S-113.
AC CURRENT		
a. No current at output terminals. No standard meter reading.	Defective potential transformer T-102.	Check input and output voltages of T-102. Check resistance of primary of T-102, 1 ohm. Check continuity of secondaries of T-102, 1.5 to 75 volt range.
	Faulty switching circuit.	Check S-103, S-110, and S-113.
	Faulty current transformers.	Check primary of T-103 for open circuit. ± Terminal to: — Resistance 20.0 A, 10.0, 5.0, 2.0, 1.0, 0.5 — Less than 1 ohm 0.2 — 6 Ohm 0.1 — 18 0.05 — 60
b. Very little or no current at output terminals, but standard meter reads.	Faulty current transformers.	Short circuit in primary of current transformer. Check resistances as per AC Current, faulty current transformers.
	Short circuit across current output terminals.	Check, remove short circuit.
c. Current at output terminals, but standard meter does not read.	Defective meter.	Check and replace of necessary.
	Defective current transformer.	Check meter winding (secondary) of T-103, resistance is 22 ohms.
AC MILLIVOLTS		
a. No voltage at output. No standard meter reading.	Same causes as AC Volts, a and b.	Check under same symptoms as per AC Volts, a and b.

Table 5. Trouble Chart, (cont'd).

SYMPTOM	CAUSE	REMEDY
b. Voltage present at output terminals, but no standard meter reading.	Potential transformers.	Check continuity and voltage output of 75 volt winding of T-102.
	Metering circuits.	Check switching circuits for continuity or short circuits, S-103.
	Defective meter.	Check meter, replace if necessary.
c. Standard meter reads, but no voltage at AC millivolt terminals.	Open voltage divider.	Check R-124 through R-133.
	Defective AC MILLIVOLTS switch S-106.	Check contacts and wiring.
	Faulty switching circuits.	S-103, S-113, and S-106.
AC MILLIAMPERES		
a. Meter reads, but no output at terminals.	Open decade resistance.	Check decade resistances.
b. All other symptoms check as per AC Voltage troubles.		

SUPPLEMENTARY DATA

Technical Summary

Tube Complement

One type 836 rectifier tube is used in the high voltage power supply.

External AC Power

A stable power source of 115 volts, 50 to 400 cps, 250 volt-amperes is required. The power source should have a short-time stability of ±1% or a voltage regulator should be used. Electrical connections are provided so as to permit external variable frequency or fixed frequency power generators in the range of 50 to 400 cps to be used. The usual power source is 115 volts, 60 cycles. The frequency of the ac outputs is that of the power source. The nominal line current consumption under full load conditions is 2.8 amperes at 50 cps; 1.4 amperes at 60 cps; and 1.6 amperes at 400 cps.

Accuracy of Calibration

The equipment is accurate to ±.5% at full-scale on all ranges with the calibration charts. The over-all accuracy on all ranges without the chart is 1% at full-scale. Under optimum conditions measurements can be made to 0.25% using the calibration charts.

Voltage and Current Calibration Ranges

Most commercial instruments fall within the ranges given in Tables 6 and 7. The Model 829 AC-DC Instrument Calibration Standard will calibrate within ±0.5% in these ranges.

Table 6. Voltage Calibration Ranges.

AC VOLTS		DC VOLTS	
RANGE	**MAX. CURRENT**	**RANGE**	**MAX. CURRENT**
Millivolts		Millivolts	
1.5 to 750	5 UA	0.25	.00013 Amp.
		0.5	.0003
		1.0	.0005
		2.5	.0013
		5.0	.0025
		10.0	.005
		25.0	.013
		50.0	.025
		100.0	.05
Volts	Max. Current	Volts	Max. Current
1.5	3.0 Amp	0.2	.030 Amp
3.0	2.0	0.5	.030
7.5	1.0	1.0	.025
15.0	0.50	2.0	.025
30.0	0.20	5.0	.025
75.0	0.15	10.0	.025
150.0	0.08	20.0	.020
300.0	0.07	50.0	.015
750.0	0.02	100.0	.015
1500.0	0.02	200.0	.015
		500.0	.015
		1000.0	.010
		2000.0	.005

Table 7. Current Calibration Ranges.

AC CURRENT		DC CURRENT	
RANGE	**MAX. BURDEN**	**RANGE**	**MAX. BURDEN**
Milliamperes		Microamperes	
1.5	10,000 Ohms	2	10,000 Ohms
3.0	10,000	5	10,000
7.5	10,000	10	10,000
15.0	10,000	20	10,000
30.0	10,000	50	10,000
50.0	1.0 VA	100	10,000
100.0	2.0	200	10,000
200.0	2.0	500	10,000
500.0	2.0		
Amperes		Milliamperes	
1.0	2.0 VA	1	10,000 Ohms
2.0	10.0	2	10,000

Table 7. Current Calibration Ranges, (cont'd).

AC CURRENT		DC CURRENT	
RANGE	MAX. BURDEN	RANGE	MAX. BURDEN
Amperes		Milliamperes	
5.0	15.0		
10.0	40.0	5	10,000
20.0	40.0	10	10,000
		20	10,000
		50	0.2 VA
		100	0.4
		200	1.0
		500	1.5
		Amperes	
		1	3.0 VA
		2	6.0
		5	15.0
		10	45.0
		20	50.0

TABLE OF REPLACEABLE PARTS

Introduction

The Table of Replaceable Parts included in this section lists all electrical parts for maintenance and procurement purposes in case of failure. These parts can be obtained from the Radio Frequency Laboratories, Inc., Boonton, New Jersey.

Reference Symbols

The reference symbols given in the Table of Replaceable Parts correspond to those appearing in the figures and text. Each reference symbol consists of a hyphenated combination of one or two capital letters and three or more significant figures. (For example C-101). The alphabetical portion of the reference symbol indicates the type of apparatus or component as classified.

Each component part covered by the same symbol designation is assigned a number running consecutively for 99 numbers, from 101-199.

SYMBOL	DESCRIPTION
A	Structural Parts, Panels, Etc.
BT	Batteries
C	Capacitors
CR	Rectifiers
E	Miscellaneous Electrical Parts
F	Fuses
HR	Heating Elements
I	Pilot Lamps
J	Jacks and Receptacles
K	Relays
L	Reactors
M	Meters
O	Mechanical Parts
P	Plugs
R	Resistors
S	Switches
T	Transformers
V	Vacuum Tubes
X	Sockets

Table 8. Table of Replaceable Parts

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
C-101	CAPACITOR, fixed, oil filled: 4 mf, 2000 v DC.	High voltage supply filter output capacitor.	HA-6430
C-102	CAPACITOR, fixed, oil filled: Same as C-101.	High voltage supply filter input capacitor.	
C-103	CAPACITOR, fixed, electrolytic: 40 mf, 250 v DC.	Low voltage filter.	HA-6474
C-104	CAPACITOR, fixed, electrolytic: 4000 mf, 10 v DC.	Current supply filter input capacitor.	HA-6472
C-105	CAPACITOR, fixed, electrolytic: 2000 mf, 10 v DC.	Current supply filter output capacitor.	HA-6473
CR-101	RECTIFIER, metallic: selenium; 26 v AC, 19 v DC, 0.45 amp.	Relay supply rectifier.	HA-4444
CR-102	RECTIFIER, metallic: approximately 4 v AC, 2 v DC, 20 amp.	Current supply rectifier.	HB-3089
E-101	TERMINAL BOARD, laminated phenolic: non-barrier type; incl 48 solder lug terms.	DC voltage divider and meter multiplier resistor mounting board.	HC-6601
E-102	TERMINAL BOARD, laminated phenolic: non-barrier type; incl 20 solder lug terms.	AC millivolts voltage divider.	HB-6571
E-103	TERMINAL STRIP: 20 terminals; bakelite.	Relay panel terminal strip.	HA-6489
E-104	SHUNT ASSEMBLY: contains 9 shunts mtd on bakelite panel.	Precision dc shunt, .05 to 20 amps, 100 mv.	HC-6471
E-105	TERMINAL BOARD, laminated phenolic: non-barrier type; incl 8 solder lug terms.	Current limiting resistor mounting board.	HB-6609
E-106	FUSEHOLDER: 15 amps, 250 v, 3AG; screwdriver slot knob.	Holder for F-101.	HA-1291
E-107	FUSEHOLDER: Same as E-106.	Holder for F-102.	
E-108	FUSEHOLDER: 15 amps, 250 v, 3AG; finger-operated knob.	Holder for F-103.	HA-1816
E-109	FUSEHOLDER: Same as E-108.	Holder for F-104.	
E-110	TERMINAL STRIP: 5 terminals; bakelite.	Line voltage input terminal.	HA-6488
E-111	TERMINAL STRIP: 8 terminals; bakelite.	DC current supply terminal strip.	HA-6487
E-112	SHUNT: 100 mv at 20 amps; accuracy 0.1%.	DC millivolts shunt.	HA-6447
E-113	TERMINAL BOARD, laminated phenolic.	AC-DC VOLTS, AC MV and DC UA, AC-DC MA output terminal board.	HB-6591

Table 8. Table of Replaceable Parts, (cont'd).

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
E-114	TERMINAL BOARD, laminated phenolic.	AC-DC AMPS and DC MV output terminal board.	HB-6499
E-115	TERMINAL BOARD, laminated phenolic.	Relay panel.	HB-6596
E-116	KNOB, w/o pointer: molded phenolic; fluted knobs; brass insert for 3/8'' shaft.	Knob for T-107.	HA-6436
E-117	KNOB, w/o pointer: Same as E-116.	Knob for T-108.	
E-118	KNOB, w/o pointer: Same as E-116.	Knob for T-109.	
E-119	KNOB, w/o pointer: Same as E-116.	Knob for T-110.	
E-120	KNOB, pointer: set screw type, black.	Bridge ratio setting knob.	HA-6479
E-121	KNOB, pointer: set screw type, white.	Knob for R-143.	HA-6629
E-122	KNOB, pointer: Same as E-121.	Knob for R-144.	
E-123	KNOB, pointer: Same as E-121.	Knob for R-145.	
E-124	KNOB, pointer: Same as E-121.	Knob for R-146.	
E-125	KNOB, pointer: set screw type, black bakelite.	Bridge ratio control knob.	HA-6630
E-126	KNOB, w/pointer: molded phenolic; fluted knob; brass insert bored for 3/8'' shaft.	Knob for S-101.	HA-6631
E-127	KNOB, w/pointer: Same as E-126.	Knob for S-103.	
E-128	KNOB, w/pointer: Same as E-126.	Knob for S-105.	
E-129	KNOB, w/pointer: Same as E-126.	Knob for S-110.	
E-130	KNOB, w/pointer: Same as E-126.	Knob for S-113.	
E-131	POST, binding: non-removable knob of molded phenolic; w/o dowel.	Equipment grounding post.	HA-6634
E-132	POST, binding: non-removable knob of molded phenolic; w/dowel.	Bridge binding posts for unknown resistance and external battery connections.	HA-3688
E-133	POST, binding: Same as E-132.	Bridge binding posts for unknown resistance and external battery connections.	
E-134	POST, binding: Same as E-132.	Bridge binding posts for unknown resistance and external battery connections.	

Table 8. Table of Replaceable Parts, (cont'd).

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
E-135	POST, binding: Same as E-132.	Bridge binding posts for unknown resistance and external battery connections.	
E-136	POST, binding: screw type; brass nickel pl.	AC-DC current and DC, MV output terminals.	HA-6633
E-137	POST, binding: Same as E-136.	AC-DC current and DC, MV output terminals.	
E-138	POST, binding: Same as E-136.	AC-DC current and DC, MV output terminals.	
E-139	POST, binding: molded phenolic; locking type; black.	AC-DC VOLTS, AC-DC MA, DC, μA, and AC millivolt binding posts.	HA-6481
E-140	POST, binding: Same as E-139.	AC-DC VOLTS, AC-DC MA, DC, μA, and AC millivolt binding posts.	
E-141	POST, binding: Same as E-139.	AC-DC VOLTS, AC-DC MA, DC, μA, and AC millivolt binding posts.	
E-142	POST, binding: Same as E-139.	AC-DC VOLTS, AC-DC MA, DC, μA, and AC millivolt binding posts.	
F-101	FUSE, cartridge: 3 amp, 125 v.	Equipment fuse.	HA-6607
F-102	FUSE, cartridge: Same as F-101.	Equipment fuse.	
F-103	FUSE, cartridge: 2 amp, 250 v; quick-acting, glass body.	Current supply overload protective fuse.	HA-1289
F-104	FUSE, cartridge: 3AG, 1 amp, 250 v; quick-acting, glass body.	Voltage supply protective fuse.	HA-4227
I-101	LIGHT, indicator: w/red lens; candelabra screw base.	Plate supply pilot lamp.	HA-2856
I-102	LIGHT, indicator: w/green lens; candelabra screw base.	Equipment pilot lamp.	HA-2854
J-101	CONNECTOR, male: 20 amp, 250 v, 2-wire.	Power input connector.	HA-2866
J-102	JACK, telephone: single closed circuit, 3 cond.	External galvanometer jack.	HA-6605
K-101	RELAY, SPDT: 12 v, 8 amp; 115 v at 60 cyc non-inductive load.	High voltage discharge protective relay.	HB-6482
K-102	RELAY, 3PST: 12 v DC, 3 amp; 115 v at 60 cyc non-inductive load.	Switching circuit protective relay.	HA-6653

Table 8. Table of Replaceable Parts, (cont'd).

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
K-103	RELAY, thermal delay, SPST: 115 v AC, 3 amp.	Plate voltage delay relay.	HA-3082
L-101	CHOKE, filter: 10 hy at 100 ma; 5000 v insul.	Voltage supply filter choke.	HB-6441
L-102	CHOKE, filter: induc .015 hy at 1.2 amps; 1500 v insul, max DC resistance .096 ohm.	Current supply filter choke.	HB-6444
M-101	METER: AC voltmeter; range 75 volts adjusted to 75 ma; 50 to 440 cyc; knife-edge pointer; acc 3/4%.	AC standard meter.	HC-6438
M-102	METER: DC milliammeter; range 1 ma; resistance 100 ohms; knife-edge pointer; acc 3/4%.	DC standard meter.	HC-6439
M-103	METER: null indicator; 100-0-100 ua; resistance 1000 ohms; bakelite case.	Bridge null indicator.	HA-6606
R-101	RESISTOR, fixed WW: 800 ohm ±10% 10 w.	DC voltage divider.	H-1100-175
R-102	RESISTOR, fixed WW: 500 ohm ±10% 5 w.	DC voltage divider.	H-1100-176
R-103	RESISTOR, fixed WW: 200 ohm ±10% 2 w.	DC voltage divider.	H-1100-168
R-104	RESISTOR, fixed WW: 130 ohm ±10% 1 w.	DC voltage divider.	H-1100-169
R-105	RESISTOR, fixed WW: 82 ohm ±10% 1 w.	DC voltage divider.	H-1100-170
R-106	RESISTOR, fixed WW: 3.3 ohm ±10% 1 w.	DC voltage divider.	H-1100-174
R-107	RESISTOR, fixed WW: Same as R-106.	DC voltage divider.	
R-108	RESISTOR, fixed WW: 10 ohm ±10% 1 w.	DC voltage divider.	H-1100-173
R-109	RESISTOR, fixed WW: 13 ohm ±10% 1 w.	DC voltage divider.	H-1100-172
R-110	RESISTOR, fixed WW: 24 ohm ±10% 1 w.	DC voltage divider.	H-1100-171
R-111	RESISTOR, fixed WW: 1 meg ±.1% 2 w.	DC voltmeter multiplier.	H-1060-12
R-112	RESISTOR, fixed WW: 500 k ±.1% 1.5 w.	DC voltmeter multiplier.	H-1060-13
R-113	RESISTOR, fixed WW: 300 k ±.1% 1 w.	DC voltmeter multiplier.	H-1060-14
R-114	RESISTOR, fixed WW: 100 k ±.1% .33 w.	Meter multiplier.	H-1060-15
R-115	RESISTOR, fixed WW: 50 k ±.1% .33 w.	Meter multiplier.	H-1060-16
R-116	RESISTOR, fixed WW: 30 k ±.1% .33 w.	Meter multiplier.	H-1060-17
R-117	RESISTOR, fixed WW: 10 k ±.1% .33 w.	Meter multiplier.	H-1060-18
R-118	RESISTOR, fixed WW: 5 k ±.1% .33 w.	Meter multiplier.	H-1060-19
R-119	RESISTOR, fixed WW: 3 k ±.1% .33 w.	Meter multiplier.	H-1060-20

Table 8. Table of Replaceable Parts, (cont'd).

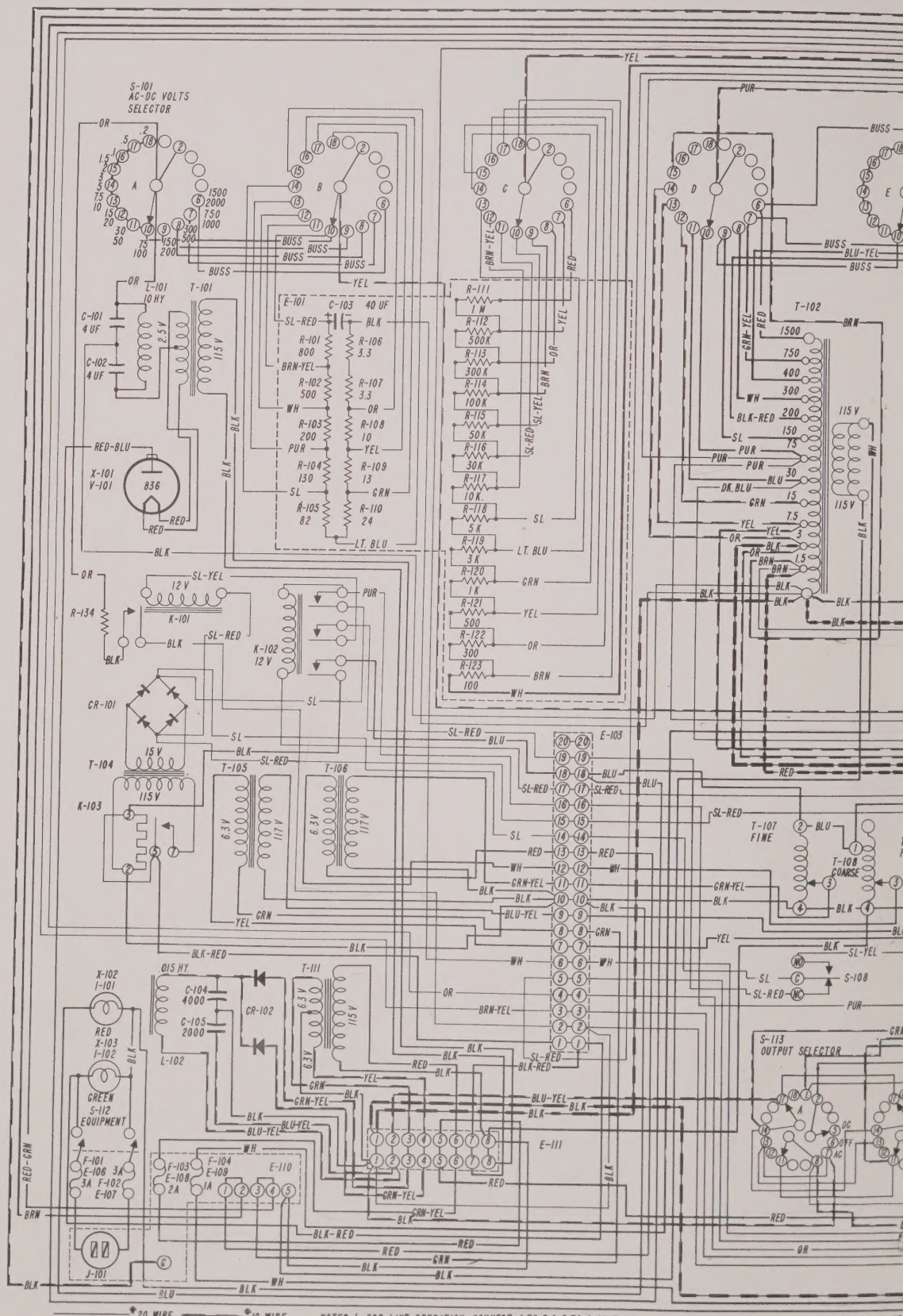
REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
R-120	RESISTOR, fixed WW: 1 k ±.1% .33 w.	DC voltmeter multiplier.	H-1060-31
R-121	RESISTOR, fixed WW: 500 ohm ±.1% .33 w.	Meter multiplier.	H-1060-21
R-122	RESISTOR, fixed WW: 300 ohm ±.1% .33 w.	DC voltmeter multiplier.	H-1060-22
R-123	RESISTOR, fixed WW: 100 ohm ±.1% .33 w.	DC voltmeter multiplier.	H-1060-23
R-124	RESISTOR, fixed WW: Same as R-121.	AC mv voltage divider.	
R-125	RESISTOR, fixed WW: Same as R-122.	AC mv voltage divider.	
R-126	RESISTOR, fixed WW: Same as R-123.	AC mv voltage divider.	
R-127	RESISTOR, fixed WW: 50 ohm ±.1% .33 w.	AC mv divider.	H-1060-24
R-128	RESISTOR, fixed WW: 30 ohm ±.1% .33 w.	AC mv divider.	H-1060-25
R-129	RESISTOR, fixed WW: 10 ohm ±.1% .33 w.	AC mv divider.	H-1060-26
R-130	RESISTOR, fixed WW: 5 ohm ±.1% .33 w.	AC mv voltage divider.	H-1060-27
R-131	RESISTOR, fixed WW: 3 ohm ±.1% .33 w.	AC mv voltage divider.	H-1060-28
R-132	RESISTOR, fixed WW: 1 ohm ±.1% .33 w.	AC mv voltage divider.	H-1060-29
R-133	RESISTOR, fixed WW: Same as R-132.	AC mv voltage divider.	
R-134	RESISTOR, fixed WW: 10 k ±10% 25 w.	Protective circuit bleeder resistor.	H-1100-188
R-135	RESISTOR, adj WW: 1 ohm ±10% 25 w; w/mtg brackets and lug terminals.	Current limiting resistor.	H-1100-182
R-136	RESISTOR, fixed WW: 2 ohm ±10% 10 w; w/mtg brackets and lug terminals.	Current limiting resistor.	H-1100-181
R-137	RESISTOR, fixed WW: 4 ohm ±10% 10 w; w/mtg brackets and lug terminals.	Current limiting resistor.	H-1100-180
R-138	RESISTOR, fixed WW: 10 ohm ±10% 5 w; w/mtg brackets and lug terminals.	Current limiting resistor.	H-1100-185
R-139	RESISTOR, fixed WW: 18 ohm ±10% 2 w.	Current limiting resistor.	H-1100-184
R-140	RESISTOR, fixed WW: 47 ohm ±10% 1 w.	Current limiting resistor.	H-1100-183
R-141	RESISTOR, fixed WW: 100 ohm ±10% 1 w.	Current limiting resistor.	H-1100-186
R-142	RESISTOR, fixed comp: 100 ohm ±5% 1 w.	Meter substitution resistor.	H-1009-182
R-143	RESISTOR, decade: 10 k total resistance, w/35 ma rating, .1% tol.	Decade resistor.	HA-6426

Table 8. Table of Replaceable Parts, (cont'd).

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
R-144	RESISTOR, decade: total resistance 1 k, .1% tolerance.	Decade resistor.	HA-6425
R-145	RESISTOR, decade: total resistance 100 ohms, .1% tolerance.	Decade resistor.	HA-6424
R-146	RESISTOR, decade: total resistance 10 ohms, .25% tolerance.	Decade resistor.	HA-6423
R-147	RESISTOR, decade: total resistance 90 k, .1% tolerance.	Decade resistor.	H-1060-30
S-101	SWITCH, rotary: 13 pos, 5 sect, 1 pole/sect.	Voltage range selector.	HB-6418
S-102	SWITCH, sensitive: SPDT; ultra-small, 10 amp, 250 v AC; w/auxiliary actuator.	Protective circuit microswitch on S-101.	HA-6429
S-103	SWITCH, rotary: 7 pos, 4 sect, 2 pole/sect.	Range selector.	HB-6420
S-104	SWITCH, sensitive: Same as S-102.	Protective circuit microswitch on S-103.	
S-105	SWITCH, rotary: 9 pos, 1 sect, 1 pole.	AC millivolts selector.	HB-6422
S-106	SWITCH, sensitive: Same as S-102.	Protective circuit microswitch on S-105.	
S-107	SWITCH, lever: 3 pos, locking type; 3 amp, 120 v AC.	Watts selector.	HB-6434
S-108	SWITCH, sensitive: Same as S-102.	Protective circuit microswitch on T-109.	
S-109	SWITCH, sensitive: Same as S-102.	Protective circuit microswitch on T-110.	
S-110	SWITCH, rotary: 9 pos, 3 sect, 1 pole/sect.	AC-DC amps selector.	HB-6419
S-111	SWITCH, sensitive: Same as S-102.	Protective circuit microswitch on S-110.	
S-112	SWITCH, toggle: DPST.	Equipment on-off switch.	HA-4337
S-113	SWITCH, rotary: decks 1 and 2, 3 pos, 4 pole; deck 3, 3 pos, 2 pole.	Output selector.	HB-6476
S-114	SWITCH, sensitive: Same as S-102.	Protective circuit microswitch on S-113.	
S-115	SWITCH, push-button: two makes.	Bridge push-to-read switch.	HB-6568
S-116	SWITCH, jack: 2 pos, SPDT.	External battery in-out for bridge.	HA-6467
S-117	SWITCH, rotary: 11 pos, 2 deck, 1 pole/deck; shorting type.	Bridge ratio setting switch.	HB-6416
T-101	TRANSFORMER, filament: 2.5 v CT at 5 amp; 5000 v insul.	High voltage rectifier filament transformer.	HB-6442

Table 8. Table of Replaceable Parts, (cont'd).

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	FUNCTION	RFL PART NO.
T-102	TRANSFORMER, potential: 50-400 cps, 75 v at 75 ma.	Potential transformer.	HB-6477
T-103	TRANSFORMER, current: multi-tapped pri; single secd.	AC current transformer.	HB-6612
T-104	TRANSFORMER, filament: 15 v at 1.5 amp; 1500 v insul; pri 115 v, 60-400 cps.	Voltage supply transformer for relay circuits.	HB-6443
T-105	TRANSFORMER, filament: pri 117 v, 60 cyc; 2500 v insul; secd 6.3 v at 3 amp, CT.	Booster transformer for Variac controls.	HB-6435
T-106	TRANSFORMER, filament: Same as T-105.	Booster transformer for Variac controls.	
T-107	TRANSFORMER, variable: 115 v input, 0-135 v output; 0.345 kva load rating.	Voltage fine control.	HC-6478
T-108	TRANSFORMER, variable: Same as T-107.	Voltage coarse control.	
T-109	TRANSFORMER, variable: Same as T-107.	Current fine control.	
T-110	TRANSFORMER, variable: Same as T-107.	Current coarse control.	
T-111	TRANSFORMER, filament: 12.6 v CT, 6.3-0-6.3; 1500 v insul; pri 115 v, 60-400 cps; secd rating 10 amp.	DC current supply transformer.	HB-6445
V-101	TUBE, electron: type 836.	High voltage rectifier.	HA-2859
X-101	SOCKET, electron tube: 8 cont.	Thermal delay relay socket.	HA-2628


S-101 AC-DC VOLTS SELECTOR
T-101
T-102
T-103
T-104
T-105
T-106
T-107 FINE
T-108 COARSE
T-111
L-101
L-102
C-101 4 UF
C-102 4 UF
C-103 40 UF
C-104 4000
C-105 2000
R-101 800
R-102 500
R-103 200
R-104 130
R-105 82
R-106 3.3
R-107 3.3
R-108 10
R-109 13
R-110 24
R-111 1 M
R-112 500K
R-113 300K
R-114 100K
R-115 50K
R-116 30K
R-117 10K
R-118 5K
R-119 3K
R-120 1K
R-121 500
R-122 300
R-123 100
R-134
X-101 V-101 836
X-102 I-101
X-103 I-102
K-101
K-102
K-103
CR-101
CR-102
E-101
E-103
E-110
E-111
S-108
S-112 EQUIPMENT
S-113 OUTPUT SELECTOR
J-101
F-101 E-106 3A
3A F-102 E-107
F-103 E-108 2A
F-104 E-109 1A
015 HY
10 HY
2.5 V
6.3 V
12 V
15 V
115 V
117 V
RED
GREEN
BUSS
BLU-YEL
20 WIRE
18 WIRE
14 WIRE
10 WIRE
6 WIRE
NOTES: 1. FOR LINE OPERATION CONNECT 1 TO 2 & 3 TO 4 ON E-110.
2. FOR VARIABLE FREQUENCY INPUT CONNECT 2 TO 4 AND INSERT V.F. POWER INTO 2 & 5 ON E-110.
3. ALL CAPACITORS IN MF.
4. ALL RESISTORS ARE IN

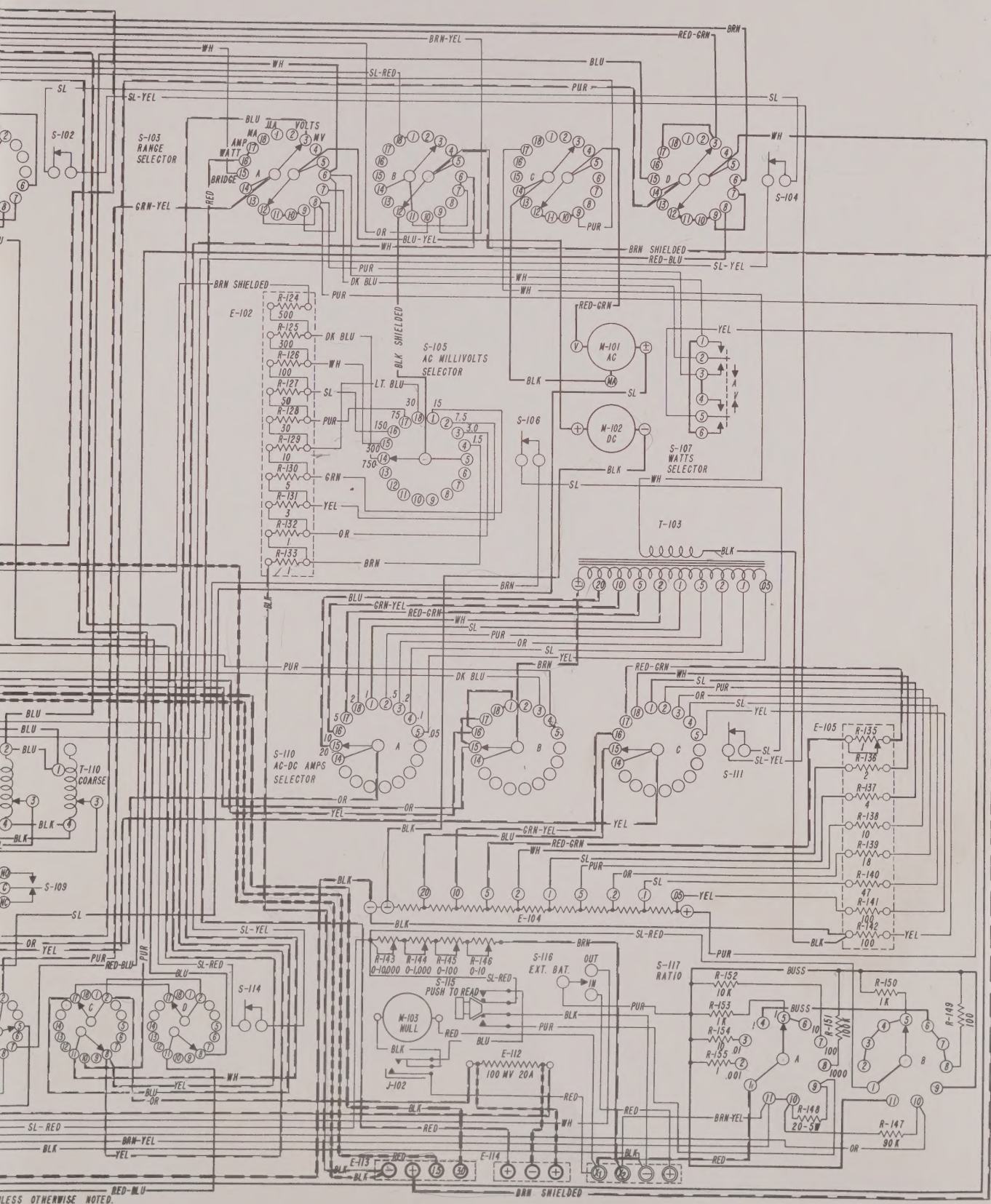


Figure 15. Schematic Diagram of Model 829 AC-DC Instrument Calibration Equipment.

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